IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS)
e-ISSN: 2319-2380, p-ISSN: 2319-2372. Volume 12, Issue 2 Ser. II (February 2019), PP 75-83
www.iosrjournals.org

Impact of Weather on Seasonality of Phytophagous Mites and Their Natural Enemies Associated With Citrus in Vidharbha Region of Maharashtra, India

Anjitha George, C N Rao, Sonali Ghike and V N Dhengre
ICAR-Central Citrus Research Institute, Nagpur, Maharashtra-440033, India
Corresponding Author: Anjitha George

Abstract: *Plant inhabiting mites on major citrus cultivars from three districts in Maharashtra, India and their associated natural enemies were documented during spring, summer and autumn seasons through random surveys for five consecutive years. Six phytophagous mite species viz., Eutetranychus orientalis (Klein), Brevipalpus rugulosus Chaudhri, Akbar & Rasool, Polyphagotarsonemus latus (Banks), Schizotetranychus sp (Tetranychidae)., Eotetranychus sp. (Tetranychidae), Phyllocoptruta oleivora (Ashmead) (Eriophyidae) and five predators were recorded. P.latus was the dominant species on nursery seedlings; Eutetranychus orientalis and Brevipalpus rugulosus on foliage and fruits in mature orchards and total mite density was considerably high during the months viz., April to June followed by October to December. Positive correlation of mite density with maximum and minimum temperature; negative correlation with rainfall and relative humidity was found to influence seasonal incidence on different citrus cultivars under study. Irrespective of the cultivar, all the weather factors had about 41 and 51% (R^2) impact on incidence of mites in citrus crop under open field and nursery, respectively. Overall, this study has thrown a light on predator composition, seasonal abundance of citrus mites with their preference for citrus cultivars and their peak activity over a period of 12 months so that accurate and timely control measures can be adopted for the effective management of mites.*

Keywords: *abiotic factors, predators, citrus, mites, species composition, incidence*

Date of Submission: 13-02-2019 Date of acceptance: 28-02-2019

I. Introduction

Phytophagous mite species are well known for causing considerable damage in major crops (Hoy, 2011) including fruit crop like citrus (Childers and Abou-Setta, 1999). About 25 phytophagous mite species out of 54 have been reported on citrus which is a serious pest especially during spring and autumn seasons (Dhooria et al., 2005; Kalidas and Shivankar, 1994). Economic losses due to these mites are quite substantial; amidst erratic climatic conditions which favor them (Abou-Setta and Childers, 1989). Nymphs and adults of brown spider mite, *Eutetranychus orientalis* Klein suck the sap preferably from upper leaf surface of leaves leading to chlorosis and finally drop down. Constant feeding on chlorophyll results in a speckled appearance and older leaves look like dusted. Rind disorder' on Kinnow orange due to *Brevipalpus rugulosus* (Dhooria et al., 1997); "Mangu disorder" on Sathgudi fruits in Andhra Pradesh and 'Rusting" on Grapefruit and "*lalya*" on Nagpur mandarin due to *Phyllocoptruta oleivora* (Ashmead) has been reported in India (Rao et al., 2012). Broad mite, *Polyphagotarsonemus latus* (Banks), is an important pest of tropical and temperate crops such as cotton, citrus, tomato, potato, chili-pepper, beans, papaya and mango (Hill, 1975) and damage concentrated on the young leaves, but sometimes cause damage to specific plant parts like stem, flower, or tips of shoots.

Pest population fluctuates with changes in biotic and abiotic factors (Roush and Mc Kenzie 1987) and these factors influence the ecology of plant-feeding mites on citrus. Abiotic factors like temperature, rainfall, humidity, photo-period and wind direction (Turi et al., 2012) have influence on developmental time, survival rate and fecundity rate of these species. Knowledge of different parameters favoring the survival of each pests to be more precise its microclimate is very important to identify the weak link for its management. Accurate identification of the species along with relative abundance of natural enemies assists to define strategies of management. The objectives of present study were to update the phytophagous mite species in major citrus growing belts in Vidharbha region, their abundance and peak date along with natural enemies, seasonal population fluctuation with major weather parameters on nursery seedlings and mature citrus orchards as a first step toward development of control programs.

II. Materials And Methods

***Sampling unit*:** Fixed plot studies were undertaken at ICAR-Central Citrus Research Institute (CCRI) farm (21°14' N, 79°08' E), Nagpur, Maharashtra, India on four seedlings viz., *Citrus limonia* Osbeck (rangpur lime), *Citrus jambhiri* Lush. (rough lemon), *Citrus reticulata* Blanco (Nagpur mandarin budlings), *Citrus aurantifolia* Swingle (acid lime seedlings) ; in open field (< eight year old trees), on *C. reticulata*, *Citrus sinensis L.* (Mosambi), *Citrus grandis* L. (Pommelo), *C. aurantifolia* at 6x6 m spacing. Standard practices of intercultural operation, weeding, fertilizer application and plant protection measures were followed uniformly across the fixed plots.

In nursery, ten leaves each from 20 seedlings were observed and in young citrus orchards, ten leaves each /tagged tree were collected at random from ten plants of each cultivar from four quadrants; north, south, east and west. Leaves were kept inside zip plastic bags and transported to the laboratory inside a portable ice box. In the laboratory, a stereomicroscope was used to quantify the mite density (population/leaf) (Leica A205) at meteorological weeks.

Considering the diversity of mites incidence in citrus, a total of 80 orchards were taken for documenting phytophagous mites and their natural enemies from different locations viz., Pipla Kinkheda, Kohli and Kotwalbardi area of Nagpur district, Warud area of Amravati district and Ashti, Sahur area of Wardha district in Maharashtra state were covered. 50 symptomatic leaves from the outer part of the tree canopy with presence of tetranychid, tenuipalpid or tarsonemids were collected at each sampling site for recording the natural enemies. Under a stereomicroscope, total number of individuals of each group of predators were recorded.

Corresponding to the flushing seasons, data was collected in three phases: (a) April to June with high temperatures and low relative humidity (RH) (b) July to October with medium temperatures and high RF with rainfall and (c) a third period with mild temperatures and high RH (November to February). The data regarding abiotic factors (temperature, humidity, rainfall) and mite density (population per leaf) was correlated. Metrological data was obtained from Indian Meteorological Division website, www.imdnagpur.gov.in.

Statistical analysis: The mean mite population on different citrus cultivar and natural enemies per symptomatic leaf were recorded. Two way analysis of variance (ANOVA) was performed by taking standard meteorological week (SMW 1-51) as factor 1 and cultivar (four each in nursery and open field) as factor 2 using SAS 9.3, and significant effects were noted. Further, a multiple comparison was done among all the main effects and interactions to identify the homogenous effects using Tukey's honestly significant difference (HSD). Correlation between abiotic factors (maximum and minimum temperature, relative humidity and rainfall) mites per leaf (pooled data of 4 years) on each citrus cultivar was established to identify key meteorological factor through simple correlation and regression studies(Gomez and Gomez 1984) using SAS 9.3.

III. Results

Roving survey results revealed the abundance of three phytophagous mites viz., *Eutetranychus orientalis* (Klein) (Family: Tetranychidae) *Brevipalpus rugulosus* Chaudhri, Akbar & Rasool (Family: Tenuipalpidae) and *Polyphagotarsonemus latus* (Banks) (Family:Tarsonemidae) (Fig. 1). In-addition, two tetranychid mite sp., *Schizotetranychus* sp. and *Eotetranychus* sp., an eriophyid mite, *Phyllocoptruta oleivora* (Ashmead) were documented on leaves and fruits of *C. reticulata* respectively, during 2013-14. Frequency of appearance of *E.orientalis*, *B.rugulosus* and *P.latus* in the orchards sampled (%) indicated that *E.orientalis* preferred *C. grandis* (33.77%) followed by *C. aurantifolia* (28.63%); *B.rugulosus* for *C. sinensis* (55.15%) and *C. reticulata* (24.44%); *P.latus* for *C. grandis* (30.81%), *C. reticulata* (26.15%) and *C. sinensis* (26.75%).

Among the bio-agents, chrysopid predator *Mallada desjardinsi* (Navas) was predominant one found feeding on different stages of mites (Table 1). Grubs of *Oligota* sp. (Staphylinidae) were found feeding on the eggs of *E. orientalis* apart from other life stages while other predators were feeding on the larval, nymphal and adult stages. Higher number of *Oligota* grubs and *M. desjardinsi* were found associated with *E.orientalis.*

The overall abundance of phytophagous mites was significantly influenced by cultivars and Standard Meteorological Week (SMW) (df=95,288; F value= 36.64, P <0.0001) indicating the susceptibility of citrus cultivars to this pest. However, seasonal incidence of mites was also significantly influenced by cultivar (df=3, F value= 102.13, P <0.0001), standard meteorological week(df=23; F value= 90.94, P <0.0001) and their interaction (df=69; F value= 15.70, P <0.0001). Further, Tukey's HSD revealed that the among the four citrus cultivars in nursery, highest mite density of 14.46±0.28 in *C.reticulata* followed by 14.04±0.28 per leaf was observed in *C.jambhiri* (p<0.001) while lowest in acid lime (7.56 ±0.28) (Fig.2). Pooled data showed that mite density was significantly highest during SMW 18 (36.12 mites/leaf) followed by a second peak during SMW 42 (23.87 mites/leaf) irrespective of the cultivars; lowest mite density of 1.87 and 1.63 mites per leaf was recorded SMW 32 and 29, respectively (Fig. 3). In general, within cultivar-SMW interaction, mite density was significantly maximum on *C.jambhiri* (43.25±1.40; p<.0001) but was at par with *C. limonia* (41.75±1.40;

p<.0001) during SMW 18 (Fig.4). During second peak, *C.jambhiri* again had highest mite density during SMW 42 (38.75 ± 1.40; p<.0001) but at par with *C.reticulata* during SMW 45(35.50 ±1.40; p<.0001).

Based on frequency of appearance of mites on different cultivars, *P. latus* (Broad mite) was the predominant species on young flush leaves mostly on seedlings while *E.orientalis* was found on matured leaves both on seedlings as well as trees. However, incidence of these two mites was recorded at lower levels on *C. aurantifolia* seedlings (0-17 mites/leaf). Relative abundance of *E.orientalis* in nursery was high during May-June (10-30 mites/leaf) followed by October to December (12-29 mites/leaf); *P.latus* during April (2-5mites/leaf), September (3-10/leaf) and December (1-6/leaf); *B. rugulosus* population on seedlings were insignificant.

Similar to nursery cultivars, there was significant effect on incidence of mites on four cultivars viz., *C. aurantifolia, C. sinensis, C.reticulata, C. grandis* with respect to Standard Meteorological Week (SMW) (df=95, 288; F value= 24.66, P <0.0001) indicating the varying levels of susceptibility of the cultivars to phytophagous mites. Seasonal incidence of mites was significantly influenced by cultivar (df=3, F value= 3.26, P =0.0219), standard meteorological week (df=23; F value= 57.09, P <0.0001) and their interaction effect(df=69; F value= 14.78, P <0.0001). A mean maximum mite density of 17.25 ±0.40 in *C. reticulata* and minimum of 16.13 ± 0.40 in *C. sinensis* cultivar was recorded during the period under study (Fig.5). In a year, SMW 14 recorded highest mite density of 35.18 ±0.99 mites per leaf (p<.0001) followed by SMW16 (35.00 ±0.99) and SMW 18 (28.25 ±0.99). Pooled data showed that mite density was significantly highest during SMW 14 (35.18 mites/leaf) followed by a second peak during SMW 16 (35.00) irrespective of the cultivars; lowest mite density of 7.12 mites per leaf (p<.0001) was recorded SMW 34 (Fig. 6). Incidence of mites was more prevalent on *C. reticulata* during SMW 14 & 16 with 43.25 and 42.50 mites per leaf while least preference on *C. sinensis* in SMW 2(p<.0001) (Fig.7).

E. orientalis and *B. rugulosus* were the abundant phytophagous species based on frequency of appearance on foliage and on fruits. The second peak of mite population during SMW 45 with 34 ± 1.5 and 36 ± 2.3 mites per leaf was recorded on nagpur mandarin and mosambi leaves. Average mite density ranged from 12-23, 5-13, 14-20, 7-18 mites/leaf on *C. reticulata*, *C. grandis*, *C. sinensis* and *C. aurantifolia* during SMW 14-20 (April-May), respectively. But in general, over a period of five years study, maximum mite density was recorded on *C. reticulata* followed by *C. sinensis* cultivar. It was also noticed that *B. rugulosus* was abundant on *C. sinensis* cultivar while *E.orientalis* on *C. reticulata, C. aurantifolia* and *C. grandis*. Relative abundance of *E.orientalis* in the orchards was high during April (13-24 mites/leaf) followed by October to March (9-43 mites/leaf) while *B.rugulosus* during April (2-6mites/leaf) and December (3-23/leaf).

Rust mite (*P. olievora*) infestation on fruits (Fig.8) of upto 41.25% was reported from Nandapur (Saoner), Kondhali, Mandav Ghorad (Hingna), Gumthala (Kamptee) and Linga, Sawangi, Uparwahi and Khumari (Kalmeshwar), Nagpur district; Tekoda and Sirkutni (Aashti), Wardha district and Kavitha, Achalpur, Amravati district on fruits of Nagpur mandarin and from Waghoda (Parshivni), Nagpur district on *C. sinensis* during spring flowering (Fig. 9).On an average, 25-78 nymphs and adults were observed per cm^2 area on infested fruits (n=50).

The correlation of mite density on four cultivars (*C.jambhiri*, *C.limonia*, *C.reticulata* and *C.aurantifolia*) in nursery and four in open field (*C.reticulata*, *C.sinensis*, *C.grandis* and *C.aurantifolia*) for corresponding weeks weather data (Table 2) indicated that *C.jambhiri*, *C.reticulata* (budlings), *C.reticulata* (mature trees) and *C.aurantifolia* (seedlings and mature trees) showed a significant positive correlation with temperature (maximum). Similarly, *C.jambhiri* showed a significant positive correlation with minimum temperature. Significant negative correlation with relative humidity for all the cultivars except *C.limonia* and *C.sinensis.* Negative with rainfall being significant in *C.reticulata* (budlings), *C.aurantifolia* (seedlings) and *C.reticulata* (mature orchards). In general, positive maximum and minimum temperature along with negative relative humidity- rainfall combination favored build up of mites.

The co-efficient of determination (R^2) showed that irrespective of the cultivars, all the weather factors had about 51% and 41% impact on prevalence of mites on grown-up trees and nursery seedlings, respectively (Table 3). All the cultivars have shown varied levels of mite population *viz*., *C.aurantifolia* (42%), *C.jambhiri* (62%), *C.limonia* (14%), *C.reticulata* (44%) in case of nursery while in open field, *C.aurantifolia* (40%), *C.reticulata* (35%), *C.sinensis* (40%) and *C.grandis* (24%) individually in the regression studies.

IV. Discussion

Seven phytophagous mites namely viz. spider mites, *Eutetranychus orientalis* Klein and *Panonychus citri* McGregor (Family: Tetranychidae); false spider mites, *Brevipalpus phoenicis* Geijskes and *B. californicus* Banks (Family: Tenuipalpidae); tarsonemid mites, *Polyphagotarsonemus latus* Banks (Family: Tarsonemidae) and eriophyid mites, *Eriophyes sheldoni* Ewing and *Phyllocoptruta oleivora* Ashmead (Family: Eriophyidae) have been reported as serious pests of citrus from different parts of India (Cherian, 1931; Dhooria et al., 1987; Nagarajan, 1967). In India, *Schizotetranychus* sp. *baltazari* Rimando (Tetranychidae: Acari) is said to have attained a major pest status in the peninsular states of India viz., Kerala, Karnataka and Tamil Nadu(Kottalagi, 2013). In our surveys, *C.sinensis* fruits with chlorotic spots were collected and later confirmed to be due to the attack of *Schizotetranychus* sp. *P. oleivora* epidemics in certain citrus pockets resulted in rusting or blemishes caused by the presence of the citrus rust mites which lower the grade of the fruits in addition to reduced size. It was also noticed from the fruit samples collected that mite attack was more on shaded side than on fruits directly exposed to sunlight. Studies on orange trees where *P. oleivora* showed that untreated tree having higher mite populations (101.6 mites/ cm^2) as compared to those from treated tree. The fruit weight, their diameter and their volume was 29.9 g, 4.5 mm and 34 cm lesser than the treated tree respectively (Nascimento et al., 1984). Mite diversity of selected citrus orchards in southern Spain reported *E.orientalis* to be the dominant tetranychid species in orange and lemon trees, whereas *Tetranychus urticae* was slightly more abundant in mandarins among the 13 phytophagous mites recorded (Vela et al., 2017).

Chrysopid predator, *M.desjardinsi* was the most abundant neuropteran collected in our survey and therefore, it may be playing a part in the natural control of spider mites in citrus. Among fourteen species of predators reported during the survey associated with tetranychid mites in Valencian citrus orchards (eastern Spain) during 2004 to 2007, *Stethorus punctillum* Weise (Coleoptera: Coccinellidae), *Conwentzia psociformis* (Curtis) (Neuroptera: Coniopterygidae) and *Chrysoperla carnea* Stephens (Neuroptera: Chrysopidae)were the predominant insect predators (Garcia-Maria et al., 1983; Ripolles et al., 1995). Under laboratory conditions, *M. desjardinsi* has been reported to consume on an average 504.40 nymphs of *E.orientalis* in no choice feeding tests (George et al., 2016). Another insect predator found on *E.orientalis* was grubs of *Stethrous* sp. and *Parastethorus indira* on nymphs and adults of spider mites. *Stethorus punctillum* was found to be the most abundant coccinellid in citrus orchards in Valencia (Alvis, 2003) and is well known as a predator of tetranychid mites (Roy et al 2003). The gall midge *F. acarisuga* reported in our study is a frequent dipteran predator which play an important role in controlling spider mite populations in other crop systems (Calvo et al., 2003; Chazeau, 1985). Predatory mites like Phytoseids were not found in our surveys.

Broad mite (*P.latus*) infestation was found more confined to young seedlings with less than 15 days old flush leaves. Findings of Pella *et al*.(2000) also substantiate the fact that *P. latus* infestations tend to be concentrated on young leaves of citrus. Population count of *P.latus* was also more in the nurseries due to the high/low temperature with high humidity (>70-90%) combinations. Humid weather (75% to 90% RH) is needed for *P. latus* development and that hot, humid weather during exposure to broad mite feeding seems to intensify the symptoms of damage (Jones and Brown, 1983).

Effect of abiotic factors on incidence/seasonality of different mite species on different citrus cultivars were also studied. The mite population increased with rising temperature especially during summer months and then drastically reduced during monsoon season due to fall in temperature and high rainfall. A second peak with rise in minimum temperature -relative humidity favored multiplication of mites till December. Ghoshal *et al*.(2011) studied the seasonality of false spider mites on guava and observed average population size in November and January with its peak population in May when the mean temperature, relative humidity and rainfall were 31-20 °C, 72-62% and 1.05 mm respectively. In our studies, the abundance of mites was observed in two peaks: April-May and October to December extended upto February in certain years. Several authors have reported maximum population of *E. orientalis* on citrus during May-June as well as in September (Smith Meyer, 1981; Patil, 2003). Mite population has also been recorded mainly during winter months, i.e., second fortnight of December to second fortnight of February with average of 5–6 mites/shoot/vine (Kulkarni et al., 2008). While Lal (1982) and Ebrahim (2000) recorded the maximum population of *E. orientalis* during January-April; maximum population of phytophagous mites during low temperature *i.e* February and November in the area of Dharward, India (Patil, 2003; Bourdeaux, 1963). Two population peaks of *P. olievora* was observed on leaves and fruits in February and March/May on valencia orange. Among the abiotic factors relative humidity and rainfall were observed to be the most prominent contributors for the population fluctuation (Hobza and Jepson, 1974).

A sudden increase in mite density during April-May may be attributed to rise in maximum temperature combined with lower relative humidity while low minimum temperature with high relative humidity during October to January during 2011-16. Epidemic outbreak of citrus rust mite in certain citrus groves from three different districts in Maharashtra severely affected the marketable yield. Twelve number of rainy days with 114 mm rainfall during March to May and prolonged dry spells during monsoon season from June to August, 2015 might have caused the increased incidence levels of rust mite on spring season fruits of *C.reticulata* and *C.sinensis* grown in Nagpur and Amravati districts of central India.

Swirski *et al* (1989) also revealed that commonly, high temperature and low relative humidity would accelerate the growth of mite population. At the same time high humidity increase their population of natural enemy, especially fungi that can suppress mite population. Positive correlations between temperature and mite population and negative correlation between rainfall and relative humidity and mite population has been reported (Singla and Sadana, 1998). According to Ebrahim (2000), optimum temperature for development is between 30 to 32℃ and it developed well at high humidity and particularly after rain. While in the case of relationship between the rainfall and mite density, there was significant negative correlation present except for cultivars like *C.jambhiri* and *C.limonia*. Although it is obvious that as rainfall increases, the mites population will be decreased but they have weak dependence upon each other. Prolonged or heavy rain with big rain drop washes off mites from host. Kumar *et al*. (2003) observed that the mite population showed a non-significant positive correlation with relative humidity and weekly rainfall in French marigold.

V. Conclusion

The data presented in this work show that many of the species known to be predators of phytophagous mites in our geographical area are present in citrus groves infested by *E.orientalis, B. rugulosus* or *P.latus.* The natural enemies found in our surveys belong to many different groups of arthropod predators, *i.e*., Coleoptera (Coccinellidae, Staphylinidae), Diptera (Cecidomyiidae) and Neuroptera (Crysopidae). They together may reduce the spatial, temporal and developmental refuges of a phytophagous mite in citrus ecosystem. This is an encouraging scenario for future research on biological control strategies against mites attacking citrus. The findings of present study will also lead to manage the citrus orchards according to the seasonal abundance of the major mite species of foliage and fruits *viz*., *E.orientalis, B. rugulosus, P.olievora* and *P.latus*. which will ultimately help in rescheduling the use of acaricides alone or in a integrated approach to minimize the damage caused by phytophagous mites in citrus.

Acknowledgements

The authors are thankful to Dr. N. Srinivasa, Professor, Dept. of Agricultural Entomology, University of Agricultural Sciences, Bengaluru for mite in identification while predators collected were identified by Dr. J. Poorani, Principal Scientist, National Research Centre for Banana, Trichinapalli.

References

[1]. Abou-Setta, M.M. and C.C. Childers.1989. Biology of *Euseius mesembrinus* (Acari: Phytoseiidae): life tables and feeding behavior on tetranychid mites on citrus. Enviro. Entomol. **18**(4): 665-669.

[2]. Alvis, L.2003. Identificacio´n y abundancia de artro´podos depredadores en los cultivos de cı´tricos Valencianos. Ph.D thesis. Departamento de Ecosistemas Agroforestales. ETSIA. Universidad Polite´cnica de Valencia.

[3]. Boudreaux, H.B.1963. Biological aspects of some phytophagous mites. Ann Rev Entomol **8**(1): 137-154.

[4]. Calvo, F.J., A. Gimenez and J.A. Jacas.2003. *Feltiella acarisuga*: primeros resultados de eficacia sobre aran˜a roja en Espan˜a. Agricola Vergel **257**: 220–225.

[5]. Chazeau, J.1985. Predaceous insects. **In:** Helle W, Sabelis MW (eds) World crop pests, Spider mites: their biology, natural enemies and control, vol 1B. Elsevier. Amsterdam, The Netherlands, pp 211–246.

[6]. Cherian, M.C.1931. *South Indian Acarina.* J. Proc. Asiat. Soc. Bengal. **27**: 141-147.

[7]. Childers, C and M. Abou-Setta.1999. Yield reduction in Tahiti lime from *Panonychus citri* feeding injury following different pesticide treatment regimes and impact on the associated predacious mites. J Entomol Zoo Stud. **23**(10): 771-783.

[8]. Dhooria, M.S., G.S. Mann and J.S. Bhalla.1997. An unusual rind disorder of Kinnow fruits associated with false spider mite, *Brevipalpus phoenicis* (Geijskes) (Acari: Tenuipalpidae) in Punjab. Abst. *Natn. Symp. on Citriculture* held at Nagpur, during Nov.17-19.

[9]. Dhooria, M.S., M.B. Bhullar and B.Mallik. 2005. *Mite pests of citrus and their management in India*. 28 pp. AINP (Agricultural Acarology).

[10]. Dhooria, M.S., S.K. Kapoor and S.P. Kapur.1987. New record of tarsonemid mite, Polyphagotarsonemus latus (Banks) (Acari : Tarsonemidae) as a pest of citrus in India. pp. 325-328. In Mukherjee AB, Somchaudhry AK and Sarkar PK (Eds.), Contributions to Acarological Researches in India. Dept. Agril. Entomology, BCKV, Nadia, W. Bengal.

[11]. Ebrahim, H.M.2000. Influence of temperature and relative humidity on the biology and life table parameters of *Phyllocoptrua oleivra* and *Aculopus pekekassi* (Acari: Eeriophyidae) On Hamlin orange in Central Florida. Egyp. J. Agricul. Res. **78**: 143-161.

[12]. Garcıa-Marı, F., F.Ferragut and J. Costa-Comelles.1983. El a´caro rojo *Panonychus citri* (McGregor): incidencia en la problema´tica fitosanitaria de nuestros agrios. Bol. Serv. Plagas. **9**: 191–218.

[13]. George, A., C.N. Rao, S. Ghike and V.N. Dhengre.2016. *Mallada desjardinsi* (Navas): A chrysopid predator on sucking and mite pests of citrus. Ind. J. Entomol. **78**(3): 201-204.

[14]. Ghoshal, S., S. Berman and M. Saha.2011. Seasonal abundance and feeding efficacy of the false spider mite *Tenuipalpus pernicis* on guava *Psidium guajava*. Acarina **19**(2): 265-269.

[15]. Gomez, K.A. and A.A. Gomez.1984. Statistical procedures for agricultural research (2 ed.). John wiley and sons, NewYork, 680p.

[16]. Hill, D. 1975. Agricultural insect pests of the tropics and their control. Cambridge Univ. Press, New York.

[17]. Hobza, R. F. and L. R. Jepson.1974. A temperature and humidity study of citrus rust mite employing a constant humidity air-flow technique. Environ. Entomol. 3: 813-822(1974).

[18]. Hoy, M.A.2011. Agricultural Acarology: Introduction to integrated mite management. CRC Press, Boca Raton Bittencourt, Florida.

[19]. Jones, V.P. and R. D. Brown.1983. Reproductive responses of the broad mite *Polyphagotarsonemus latus* (Acari: Tarsonemidae), to constant temperature–humidity regimes. Ann. Entomol. Soc. Am. 76:466–469.

[20]. Kalidas, P and V.J. Shivankar. 1994. Annual Report of the project "Studies on Chemical Control of Insect Pests of Nagpur Mandarin with Special Reference to Citrus Blackfly, Psylla and Leaf miner", NRCC, Nagpur, pp. 35.

[21]. Kottalagi, P. 2013. Bio-ecology and management of mite, *Schizotetranychus baltazari* Rimando (Acari: Tetranychidae) on acid lime. MSc.Thesis, University of Agricultural Sciences, Dharwad. p.61.

[22]. Kulkarni, N.S., S.D. Sawant and P.G. Adsule.2008. Seasonal incidence of insect pests on grapevine and its correlation with weather parameters. Acta. Horticul. **785**: 313-320.

[23]. Kumar, S., S. Prasad and R.N. Singh.2003. Population trends of two spotted spider mite (*Tetranychus urticae*) in relation to abiotic factors on French marigold (*Tagetes patula*). Ind. J. Agricul. Sci. **73**(5): 303-304.

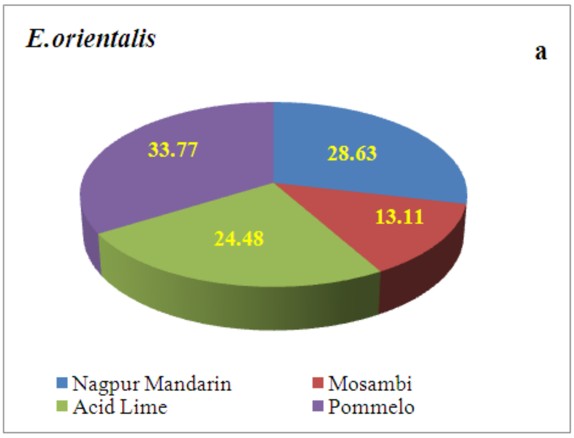
[24]. Lal, S.S.1982. Influence of weather factors on the population of spider mites (Acari: Tetranychidae) and thrips (Thysanoptera) on cassava in Kerala. Ind .J. Acarol. **7**: 5-10.
[25]. Nagarajan, K.R.1967. A preliminary study of citrus mites in Madras state. S. Ind. Horticul. **15**: 31- 35.
[26]. Nascimento, A.S., R.C. Caldas and L.M.S Silva.1984. Infestation and damage caused by the citrus rust mite, *Phyllocoptruta oleivora* Ashm. Ana. Soc. Entomol. Brasil. **13**: 237-247.
[27]. Patil, S.R.2003. Evaluation of indigenous products for the management of chilli mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae). Agricul.Sci., Dharwad, India. 106 (2003).
[28]. Pella, J.E., R. Ochoa and E. Erbe.2000. *Polyphagotarsonemus latus* (Acari: Tarsone_midae) Research Status on Citrus. PROC. INTL. Soc. Citricult. IX congr. 754-759.
[29]. Rao, C.N., V.J. Shivankar and K.J. David.2012. Insect pests of citrus fruits. Extension bulletin No.41, pp 15, ICAR-CCRI, Nagpur.
[30]. Ripolles, J.L., M. Marsa and M. Martınez.1995. Desarrollo de un programa de control integrado de las plagas de los cı´tricos en las comarcas del Baix Ebre-Montsia`. Levante Agrı´cola **332**: 232–248.
[31]. Roush, R.T. and J.A. McKenzie.1987. Ecological genetics of insecticide and acaricide resistance. Ann. Rev. Entomol. **32**(1): 361-380.
[32]. Roy, M., J. Brodeur and C. Cloutier.2003. Effect of temperature on intrinsic rates of natural increase (rm) of a coccinellid and its spider mite prey. Biocontrol **48**: 57–72.
[33]. Singla, N and G.L. Sadana.1998. Population development of Eutetranychus orientalis (Klein) on citrus: a correlation with weather factors and predators. Ind. J. Ecol. **25**: 32-35.
[34]. Smith-Meyer.1981. Mite pests of crops in Southern Africa. Sci. Bull. P. Prot. Res. Institute., Pretoria, S. Africa, 397.
[35]. Swirski, E., M. Gokkes and S. Amitai.1989. Phenology and natural enemies of citrus red mite *Panonychus citri* (McGregor) in Israel. Israel J. Entomol. **20**: 37-44.
[36]. Turi, T.H., I. Khan, F. Ullah and M. Naeem.2012. Influence of Abiotic factors on the population density of phytophagous mites on various apple cultivars. Sarhad. J. Agricul. **28**(4): 621-627.
[37]. Vela, J.M., E. Wong, J.A. Jaques, C. Ledesma and J.R. Boyero.2017. Mite diversity (Acari: Tetranychidae, Tydeidae, Iolinidae, Phytoseiidae) and within-tree distribution in citrus orchards in southern Spain, with special reference to *Eutetranychus orientalis*. Exp. Appl. Acarol. **73**(2): 191–207.

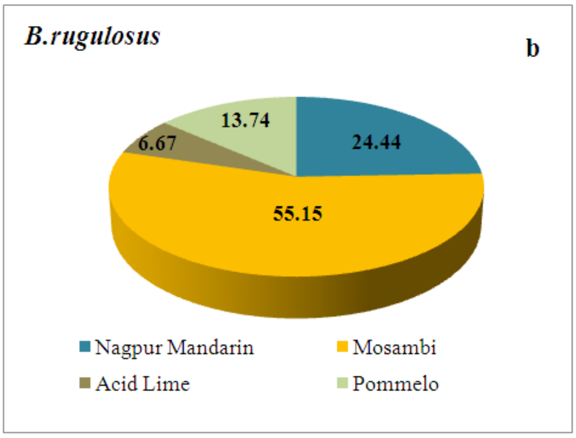
Table 1: List of predators of mites documented

Sl. No.	Name of the predators	Family	Stage of predator	Stage of mite found feeding
1	*Mallada desjardinsi* (Navas)	Chrysopidae	Larva	Nymphs and adults
2	*Stethorus* sp.	Coccinellidae	Grub	Nymphs and adults
3	*Parastethorus indira* Kapur (=*Stethorus indira* Kapur)	Coccinellidae	Grub	Nymphs and adults
4	*Feltiella* sp.	Cecidomyiidae	Larva	Nymphs and adults
5	*Oligota* sp.	Staphylinidae	Larva and adult	Eggs, nymphs and adults

Table 2 Multiple regression co-efficient between weather parameters (pooled for 2011-16) and mite population for nursery and open field during 2011-16

Cultivar	Regression Equation	R^2
Field	Y= -71.78+2.55max.Temp. -0.91Min Temp.-0.04 RF + 0.34RH	0.41
Nursery	Y= 29.03-0.28max.Temp. 0.62Min Temp-0.06RF -0.27RH	0.51
Nursery		
C.aurantifolia	Y= 20.57-0.006 Max. temp. +0.06 Min Temp-0.03 RF -0.09 RH	0.42
C.jambhiri	Y= 37.8-0.47 Max. temp+ 1.38 Min Temp-0.07 RF -0.48 RH	0.62
C.limonia	Y= -11.5+0.72 Max. temp-0.08 Min Temp-0.02 RF +0.017 RH	0.14
C.reticulata	Y= 69.25 - 1.37Max. temp+ 1. 31 Min Temp 0.11 RF -0.42 RH	0.44
Open field		
C.aurantifolia	Y= 26.63+ 0.38 Max. temp. - 0.43 Min Temp + 0.03 RF -0.23 RH	0.40
C.reticulata	Y= -69.12 +2.36 Max. temp -0.44 Min Temp -0.09 RF + 0.29 RH	0.35
C.sinensis	Y= -213.10 +5.76 Max. temp-1.99 Min Temp -0.09 RF +1.19 RH	0.40
C.grandis	Y= 68.15+ 1.70 Max. temp. -0.79 Min Temp -0.01 RF +0.11 RH	0.24





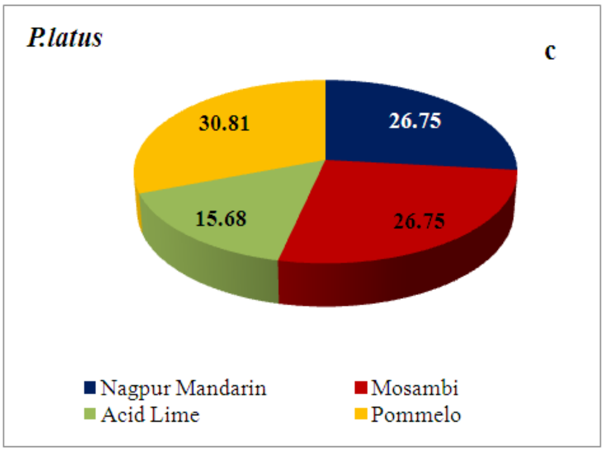


Fig. 1 a, b, c Frequency of appearance of *E.orientalis*, *B.rugulosus* and *P.latus* on citrus cultivars

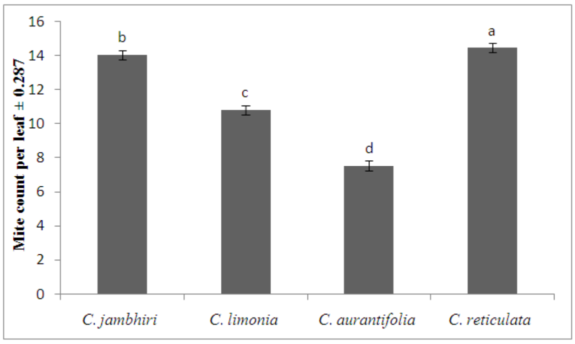


Fig. 2 Mean mite density of phytophagous mites on four citrus cultivars in nursery
(Means presented are untransformed data).

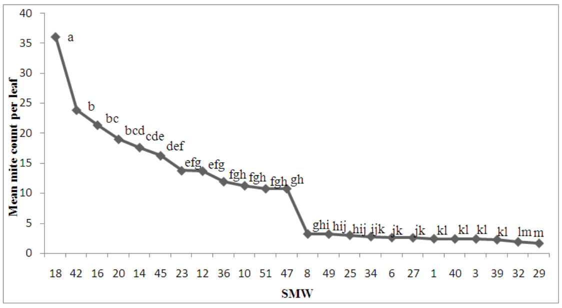


Fig. 3. Seasonal changes in the incidence of phytophagous mites on four citrus cultivars under nursery condition (Means presented are untransformed data).

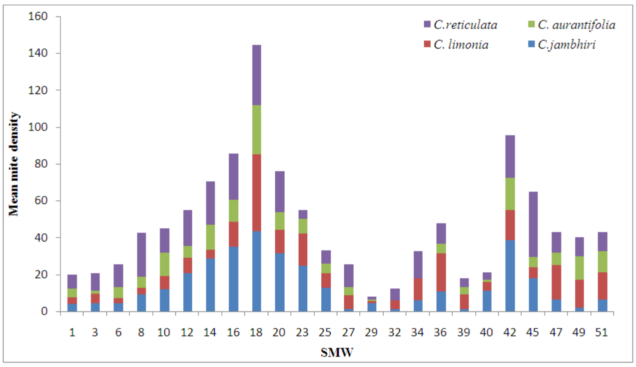


Fig.4 Seasonal changes in the abundance of phytophagous mites on citrus cultivars in nursery

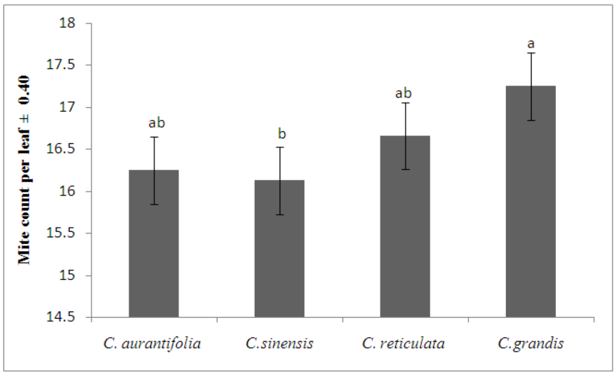


Fig. 5 Mean mite density of phytophagous mites on four citrus cultivars in open field (Means presented are untransformed data).

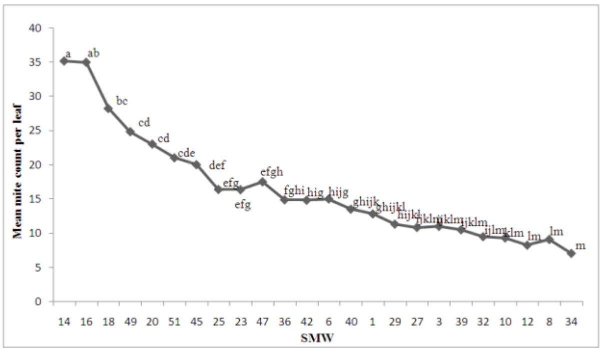


Fig. 6 Seasonal changes in the incidence of phytophagous mites on four citrus cultivars in open field condition (Means presented are untransformed data).

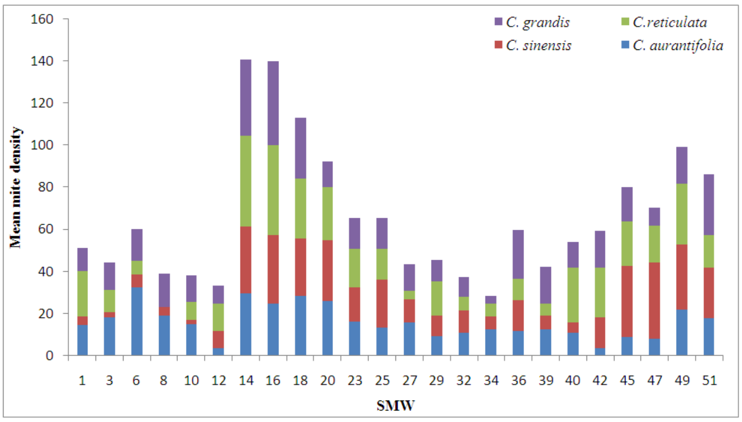


Fig.7 Seasonal changes in the abundance of phytophagous mites on citrus cultivars in open field

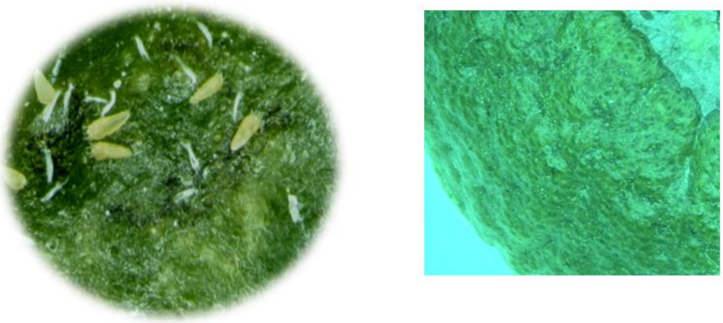


Fig. 8 Rust mite incidence on *C.reticulata* fruits

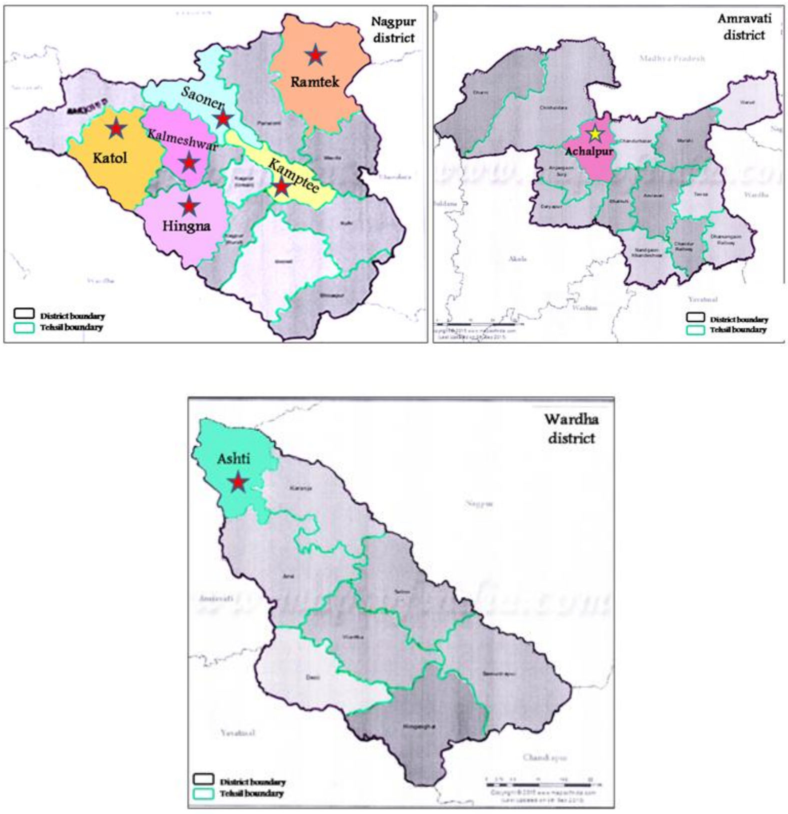


Fig. 9 Location of sampling sites of rust mite outbreak during *spring*, 2015

Anjitha George. "Impact of Weather on Seasonality of Phytophagous Mites and Their Natural Enemies Associated With Citrus in Vidharbha Region of Maharashtra, India." IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 12.2 (2019): PP- 75-83.